Optimised Air Rifle Methods for the Humane & Lethal Removal of Grey Squirrels

A Case-Study from a Manor House Estate in the North of England

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Part I: Overview

This report outlines a case study of a grey squirrel culling project in the north of England. There are several motivations for completing this report. The most pertinent are; (i) it is provided as an evidence-based approach, presenting clear data informing on the efficacy of air rifle methods (as currently, no such dataset on air rifle methods has been published). In addition, (ii) it provides a response to the claims from the Forestry Commission (and other woodland organisations) that shooting methods are an ineffective or inefficient approach for controlling grey squirrels. This claim has been made in various reports and via online resources, yet the foundation for such a position is far from unquestionable.

Indeed, in a recent report published by the Royal Forestry Society there is little mention of shooting as a method of control at all – and what brief mention it gets, there is no fractionation between shooting methods (*An Analysis of the Cost of Grey Squirrel Damage to Woodland*, Royal Forestry Society, 2021). The cost analysis provided appears to be based on the costs of large estates carrying out drey-poking activities with shotguns. The report alludes to the cost of control per-hectare, but again, concentrating on non-shooting methods (i.e., trapping). *"As with the level and cost of damage, cost of squirrel control varies significantly. This depends on the methods of control used. Most common is the use of Fenn type traps and live traps and sources tend to agree that these are the most successful, albeit more expensive, methods of control if they are used correctly. Drey poking and shooting are widely used* ***but not considered to be the most effective method*** *and best applied in combination with trapping*". (RFS, 2021; Page 15). There is no mention of using air rifles as an approach and no acknowledgement of the many volunteers / red squirrel groups and their involvement in woodland protection. In addition, the comment on shooting methods not being effective is not furnished with data and appears to be based on anecdotal reports. Furthermore, in Appendix F of the same report (Page 35), there is a section on alternative methods of control – but again, control via air rifles methods is not acknowledged.

Another report, based on a survey of land owners, does acknowledge the presence of shooting as a control method but again provides no detail on the shooting formats or methods used and reported that shooting alone was considered ineffective as a method for grey squirrel control (*Summary report on review of evidence underpinning grey squirrel policy in England*, 2014). The report states *"Shooting alone was rarely considered effective at controlling populations of grey squirrels or limiting damage to trees"* (Page 3). However, this appears to be based on anecdotal views of those surveyed and not objective empirical data. The report does acknowledge the role of volunteer groups but no explicit mention of air rifles is given (Red Squirrels northern England is credited).

For the present case study the humane and lethal removal of the grey squirrel was carried out primarily via optimised air rifle methods. These methods involved; (i) the planned ambushing of feeders / bait stations, (ii) stalking through winter woodlands, and (iii) both were complemented with thermal imaging. Ambushing took place throughout the year – though periods of high and low activity on feeders were noted. Stalking was only utilised during the winter and early spring months when the tree canopy and woodland floor were clear. In terms of other shooting methods, no drey poking took place (shotguns), or to the best of our knowledge, has ever taken place in these woodlands. A retired gentlemen did carry out some minor trapping (lethal spring traps) around the main manor house and a small part of one wood immediately proximal to it. However, few were trapped due to inconsistent re-setting of lethal traps. His services were soon discontinued (in 2019). Therefore the case study reported here is primarily based on a shooting-only and indeed shooting only with air rifles method implemented by a sole air rifle enthusiast working as a volunteer in their spare time. Consequently this project provides a clear and uncontaminated view on the efficacy of air rifle methods for the humane and lethal removal of the grey squirrel.

With a host of woodlands to cover, a plan was devised to set up more than one feeder at a time (in separate woodlands) and culling efforts split across these. Once grey squirrels were significantly reduced

(resulting in very few or no sightings across a number of visits); then new feeders in different woodlands were set up and efforts moved on to these locations. This cycle was repeated and in due course the original sites were revisited and targeted again. Therefore, the approach was to rotate the pressure across the woodlands and to return to original sites to mop up any remaining or new squirrels in the area. This approach was deemed advantageous because;

- It allowed for a footprint of pressure to be established early across the broader project rather than efforts only being focused in one location.
- It prevented a single feeder from becoming over-shot to the extent that visits from grey squirrels might reduce, while numbers in the area remain large, due to localised threat-related behavioural changes. Therefore, an unpredictable 'broken rhythm' approach was applied to the active feeders.
- It provided, at least in part, a degree of interception for wood-to-wood movement / migration from grey squirrels within the region being covered.

The project began in May 2018 and consisted of seven separate woodlands with six belonging to a manor house estate and one belonging to a neighbouring farm. In 2020 three new woodlands were added to the project from landowners surrounding the main manor house estate. This case-study report covers the period from May 2018 to September 2022. The project is on-going though only data from this time period are reported here. Throughout the project visits to the woodlands were constant, at around 2 or 3-visits per week on average. Severe weather, occasional forestry work, and the 1st pandemic lockdown prevented access at various points during the 4-year period. Severe weather impacted on a couple of years, predominantly during the month of February. In 2022 there were three severe storms in February with one storm bringing down many trees across the Lake District. Furthermore, it was not clear whether pest control / conservation represented 'essential' activity for the first lockdown of the Pandemic and so no shooting took place during that initial period until clarification was provided.

Aims: Eradication or control?

For an invasive species like the grey squirrel the gold standard would be to eradicate them from the woodlands of the UK. However, such aims also need to be tempered by what is practical and pragmatic. One view is that full eradication is presently unlikely with all current methods. For some contexts controlling numbers and suppressing growth in numbers may be all that can be achieved. This is important when assessing whether a particular approach, be it shooting or otherwise, can be viewed as being *effective*. Effectiveness needs to be assessed relative to the goals and aims of a given project mediated by various situational constraints and what is realistically attainable in that context. For example, it is possible to eradicate grey squirrels from rural woodlands with sufficient and constant pressure applied to the area through shooting and trapping. However, in more urban contexts like city parks or a University campus such approaches are difficult to implement. A project that is successful at stopping numbers from increasing or even suppressing / reducing numbers can all be seen as effective in the context of what successes could be realistically expected or achieved. In other words, this situation is more desirable than one with no control in place – where numbers would likely increase year on year. However, if judged alongside the notion that shooting / trapping can only been seen as effective if it results in the total eradication of greys then clearly such circumstances could lead to the view that these methods are ineffective – which would constitute more than a mischaracterisation of the realities of the situation. Irrespective of these subtleties, as Simbeloff has mentioned in the IUCNs report *"Turning the Tide"* the population needs to be "knocked down", before it can be "mopped up" and so success and efficacy can be seen as suppression in the first instance, followed by removal over time.

Neither “effective” or “humane”? A re-examination of the claims against shooting with air rifles.

In an online news article, the BBC reported the Forestry Commission (FC) claim that shooting grey squirrels with an air rifle was, *"not an effective or humane form of control."* (https://www.bbc.co.uk/news/uk-england-35266261). This statement may well underlie the reason the FC does not sanction shooting with an air rifle on their land. However, despite a dedicated search of their literature no actual firm evidence for the claim of air rifles being ineffective or indeed being inhumane can be found. In addition, the Forestry Commission provides no evidence that they are even aware of how an air rifle can be used / optimised for the control of grey squirrels or what such methods actually involve. Consequently this claim from the FC appears sweeping and baseless with important negative consequences for the management of grey squirrels and the conservation of woodland trees and other endangered species (i.e., the red squirrel).

Air rifles have been used in a pest control / hunting capacity of small quarry for decades, including being used for species far larger than the grey squirrel (i.e., the rabbit). The claim that air rifles are not humane sits in some friction with observations from the field by those involved in conservation and land management as well as being challenged directly by the known ballistic profiles of air rifle pellets. To examine this further, there are perhaps three main ways we could conceptualise the claims made against the use of air rifles. In terms of the claim that air rifles are inhumane this might pertain to a view that; (i) at sub 12ft.lbs, air rifles do not carry sufficient destructive energy to dispatch the grey squirrel, and in addition, (ii) that the air rifle cannot provide the downrange precision in shot placement to ensure the humane and lethal removal of the grey squirrel. These issues may also speak to the notion of effectiveness, but effectiveness perhaps also pertains more generally here to the field techniques and methods themselves. All of these possibilities will now be examined.

Evidence from Ballistics

In terms of the arguments outlined above, then a simple consultation of ballistics (based on known mathematical models) clearly supports rival interpretations. It is estimated that an air rifle pellet carrying 4ft.lbs of energy at impact is the minimum required for the humane removal of air rifle quarry (i.e., grey squirrels, rabbits, etc). For a feeder-based approach, the distance between a squirrel feeder and the shooter will typically range from around 20yds to 30yds. A .22 calibre 16grn Diabolo pellet producing 11.6ft.lbs at the muzzle will still carry 80% of its muzzle energy at 30yds (9.23ft.lbs) – more than double required for the humane removal of the species. To labour the point slightly, the level of energy carried by the same pellet is 8.55ft.lbs out to 40yds. Therefore the energy contained within the projectile is clearly more than sufficient to support the lethal and humane removal of grey squirrels (see Table 1 for a fuller ballistics report). Any concerns over the energy levels contained within an air rifle projectile can be alleviated by the science of air rifle ballistics.

Table 1: Output from the Ballistic modelling software Chairgun (Hawke Optics) for a rifle with 11.6ft.lbs of muzzle energy. The energy carried by the .22 calibre pellet is more than sufficient at distances adopted for the humane removal of grey squirrels (25yds to 30yds are typical distances) with 40yds representing a theoretical maximum and only in perfect conditions with a capable, experienced shooter.

Graph | Table | Graph & Table

Ballistics Table

Range (Yard)	POI (In)	POI (dot)	POI (clk)	Time (sec)	Vel. (Ft/s)	Vel.Res (%)	Energy (FtLbf)	Energy (%)	Mom. (Grn.s)	Mom. (%)	Drop (In)	Pen. (In)
5	-0.67	-3.74	51	0.026	562.5	99.621	11.17	96.27	278.0	98.1	-0.1	3.16
10	-0.02	-0.05	1	0.053	551.9	99.621	10.75	92.68	272.8	96.3	-0.5	3.10
15	0.35	0.64	-9	0.081	541.5	99.620	10.35	89.22	267.6	94.5	-1.2	3.04
20	0.42	0.58	-8	0.109	531.3	99.620	9.96	85.89	262.6	92.7	-2.2	2.99
25	0.18	0.20	-3	0.137	521.3	99.618	9.59	82.67	257.6	90.9	-3.5	2.93
30	-0.37	-0.35	5	0.166	511.4	99.618	9.23	79.56	252.7	89.2	-5.1	2.88
35	-1.26	-1.00	14	0.196	501.7	99.617	8.88	76.57	247.9	87.5	-7.1	2.82
40	-2.49	-1.73	24	0.226	492.1	99.616	8.55	73.68	243.2	85.8	-9.4	2.77
45	-4.09	-2.52	35	0.257	482.7	99.616	8.23	70.90	238.6	84.2	-12.0	2.71
50	-6.05	-3.36	46	0.288	473.5	99.615	7.91	68.22	234.0	82.6	-15.1	2.66
55	-8.41	-4.25	58	0.320	464.5	99.614	7.61	65.63	229.5	81.0	-18.5	2.61
60	-11.16	-5.17	71	0.353	455.6	99.614	7.33	63.14	225.1	79.5	-22.3	2.56

Importantly, the key to using an air rifle effectively in the field is not necessarily muzzle energy (assuming it is sufficient), but precision in shot placement on the quarry. It should be noted that modern multi-shot PCP air rifles are highly precise instruments. Many units are fitted with match grade barrels and quality telescopic optics. PCP rifles are also recoilless, have very low shot-to-shot variability in velocity levels (tuned units capable of 3 feet-per-second variation in shot-to-shot velocity which supports excellent consistency) and are capable of highly respectable downrange precision in shot placement on targets. These factors all contribute to make the air rifle a highly consistent instrument. In addition, when ambushing, it is typical to use a shooting stick or Bipod which provide a high degree of stability for the rifle. These factors ensure precision and consistency in downrange shot placement – with lethal and humane consequences in the hands of a competent user. Consequently, the claim that air rifles are inhumane appears to be without foundation. Finally, the claim that using air rifles is *ineffective* as a method per-se is directly challenged throughout this case study with clear data from a shooting-only (and only with air rifles) project. Before considering the actual data (Part II), an optimised 21st Century approach to shooting with air rifles is outlined so that a healthy appreciation of exactly how humane removal is implemented can be gleaned[1].

[1] The legal limit for muzzle energy on non FAC air rifles is 12ft.lbs. All rifles used on this project were sub 12ft.lbs units.

Figure 1: Modern air rifles are capable of excellent precision across hunting distances. These examples below represent 10 shots into paper targets at 30yds (many going through the same hole). The rifle was .22 calibre and rested on a shooting stick to improve stability – and were taken in outdoors conditions. Both groupings are well under the diameter of a 5p piece and show extremely consistent performance that would be lethal and humane on suitable quarry.

Figure 2: The modern precision multi-shot PCP air rifle – a tool extremely well suited for the safe, discrete, and humane lethal removal of the grey squirrel from our woodlands.

A 21st Century Optimised Approach with Air rifles

The proliferation of the grey squirrel through the woodlands of the UK is a serious problem. Consequently, this problem requires a serious 21st Century solution. Major projects concerning the lethal and humane removal of the grey squirrel from woodlands combine research, observation, and data-gathering technology. A lot of work and thought underlines successful culling projects long before any trigger is pulled. From the design of squirrel feeders (their placement and feed mix), to the use of passive infra-red (PIR)-wildlife trail cameras, establishing hides, thermal imaging and ballistic software, nothing goes unconsidered. Collectively, these resources mean that the shooter can optimise their approach in several regards, all with the objective of increasing ones efficacy in the field.

Feeder design

Feeders come in many designs, but it is preferable to use those with a platform and a flip-top lid that only squirrels can access. Note – some commercially available feeders are not fit for purpose. Not only will grey squirrels chew and destroy them in a few days, but rats / mice can access the feed as they can also lift the overly thin and light lids. Therefore, with a flip top design, a decent heavy lid is required to ensure only squirrels are taking the food. Open tray feeders should be avoided as feed can be taken by numerous species (including birds) and it can prove expensive. A compromise here is to place a couple of handfuls of feed onto the platform to attract songbirds and allow the nutty smells to move through the woodlands. This still protects the main food reservoir, but also gets the birds used to the feeder and brings them in. The songbird activity itself can help to attract squirrels to the feeder – but this way – the songbirds cannot raid the entire food store. Feeders of a reasonable size can last longer before the need to top them up is required. However, overly large feeders lack discretion if the woodland is accessible by the public – so often smaller and more discrete can be preferred though they will require more visits to top them up. A balanced approach that seeks to mitigate these factors should be adopted in any given situation.

Feeder placement

The locations chosen for implementing an optimised feeder-based approach are not random but based on an assessment of the region within the woodland. If possible it is always preferable to examine the area for the presence of dreys. This is not an exact science as grey squirrels can build dreys inside old trees with no external signs of their presence. However, external twig-based dreys are also common and can be located easily in the winter months. The feeder itself needs to be mounted on a tree that can also provide a safe backstop to prevent pellets straying beyond the target. It is best not to mount the feeder on a tree hosting the actual drey, but one in the general vicinity. Greys squirrels have a tendency to use 'highways' - established and trusted routes through the woodlands. Ideally, the feeder tree should be on this highway or very near to one. The locations for the ambush positions are chosen for optimal cover and distance to the feeder. In terms of cover for the individual, evergreens and holly bushes can provide year-round cover in terms of being effective backdrops and can be complemented with some hide work by either building natural hides, some leaf-netting, or a pop-up hide.

Feed

The natural feeding behaviour of the grey squirrel follows what is known as the *'Optimal Foraging Theory'*. Here the food choices are based primarily on an assessment of the profitability of different food types, mitigated by the energy required to attain the food. By this account, squirrels are thought to always

prefer food that is energetically favourable based on the nutritional content minus the energy it takes to obtain the item. The more calories contained within the food, the more likely it will be chosen first by the squirrel and pursued more vigorously. However, this foraging behaviour is also mediated by other factors such as the perceived risk from trying to attain the food sources (i.e., from predators). Risk perception itself is further mediated by both the lack of safe signals in the area (like bird activity) and the actual physical presence of threats (raptors, mustalids, etc). What the squirrel is really interested in is the best / most energetic meal in the woods, that is really easy to attain, and they perceive no or low threats in getting at it. So these factors trade off against each other and ultimately influence the squirrel foraging and feeding patterns.

In terms of what food works well in a feeder, peanuts provide an ideal staple as a base ingredient and are perfectly suitable. Some shooters prefer to use wheat, barley or maize. However, many report the greys not being overly interested in these less caloric offerings after some initial interest wanes. But peanuts never fail. On the whole grey squirrels can show more interest in a feed 'mix' rather than just one food type – as additional items can also provide more smells (to attract them in) and the activity of rummaging itself across food sources can be more stimulating for them. Peanuts are perfectly fine on their own a lot of the time – but a mix appears to work a little better. Other additional foods to add can include; large striped sunflower seeds, sunflower seeds, and black sunflower seeds. The squirrel will prefer the nuts and may ignore some of the other goodies, but the presence of some of the other items can be for smell and it keeps them on the feeder rummaging and blissfully unaware of the shooters presence nearby. When establishing a feeder in a given area it can be good to complement the food mix with a scent attractant (i.e., aniseed oil) or smear a chocolate nutty spread on the tree hosting the feeder (but also facing the shooter). The nutty spread, when placed correctly, will also articulate the squirrel into a position which should present the individual with a perfect brain shot in through the top on the skull of the grey squirrel.

Throughout the year grey squirrels can show variations in their foraging and feeding behaviour. For example, fewer greys will visit feeders during late summer / early autumn months. This is due to the availability of the natural woodland fruit and nuts during this period. Here grey squirrels are biologically hardwired to spend time in the tree canopy and harvest the banquet on offer. Towards late autumn and early winter grey squirrels will also begin caching shelled nuts / acorns to help them survive the harsh winter and early spring. They will show a reduced interest in feeders and are difficult to shoot due to the available cover still present in the woodlands at this time. Many conservationists will stop shooting them around this time and wait until early November, when food has fallen to the ground and the tree canopy has lost much of its foliage. At this time it can be a good idea to add items to the feeder with a higher caloric value, but are also still shelled (i.e., hazelnuts, monkey nuts, walnuts, chestnuts, fallen acorns). There are several reasons for doing this. One is to get the feeder to compete for interest again, and against the food the woodland is providing naturally – but will also now be decaying. Another reason is to encourage caching behaviour. This now gives the squirrel two reasons to visit the feeder, one to eat and one to cache. Greys have been observed coming into a feeder containing these more substantive food sources, even though the woodland floor may also contain similar items (fallen acorns, hazelnuts, chestnuts, etc). The reasons for this are unclear but this may reflect the fact that the feeder is one single spot where all the goodies are, and is favoured rather than expend energy to find the best food spread out on the woodland floor. Once the feeder is stocked with such items what is often observed is a fast moving grey squirrel coming into the feeder, it will take the nut, quickly assess it, and invariable (at this time of the year) might run off quickly with the nut to bury it. However, after doing this once or twice the grey squirrel will stop to feed and not cache due to the energy already used in caching. Here the squirrel will often pause to nibble open the outer casing to get at the inner nut. This takes time and they tend to stay still when doing this, providing an ideal opportunity for the unhurried, humane, and lethal removal of the

quarry. Once the grey squirrels have started to return to the feeder, one can swap back to a more typical feed – it is only a method to be tried across a few weeks at this time.

Figure 3: A flip-top feeder placed on a broad deciduous tree in the winter woodlands. Note the thick / heavy lid on the feeder. Note also the winter feed mix containing a variety of nuts including some more substantial items to ensure the feeder gets attention for feeding and caching during this time.

Working the target space

On occasion it might be necessary to work the woodland floor around the feeder. The reasons for this are to provide additional clear viewing of the ground area to be targeted but also to create smells for the grey squirrel to come into the area and investigate. Overgrowth should be carefully trimmed between the tree hosting the feeder and the ambush position to allow the pellet to travel unimpeded and without deflection into its target area. This trimming should not be over-done. In some contexts the bare area may make the grey squirrel weary of predators and thus reluctant to enter the area (and so sometimes it is wise not to do this). However, on occasion it can be very effective and can be a method worth exploring. Permission should be sought to carry out such trimming and of course, healthy trees / branches should not be touched – the process outlined here is more concerned with redundant foliage in the area (woodland grass, brambles, bracken, dead and fallen branches, etc). It will not always be possible to work the space in this way, but when it can be implemented, it can assist with culling practices. Irrespective of working the ground space an assessment of the materials that may impede the travel of the pellet to the feeder area should be undertaken.

Figure 4: Working the target space around the feeder can help in terms of providing a clear route into the space so the pellet can travel unimpeded and free from deflections. Working the soil a little also provides smells to attract the grey squirrel to the area. However, the trick is not to over-work / over-clear the area. The grey squirrel still needs to feel safe from predators and this feeling is mediated by the presence of cover.

Hides for Ambushing

For ambushing it is useful for the individual to remain as hidden as possible. The summer months can, in some situations, provide enough cover on its own and simply using the shadows and a solid backdrop is often all that is needed. However, for the rest of the year what the woodlands provide naturally can be insufficient. In these circumstances a shooting hide is invaluable. Hides can be built from natural materials (fallen branches, leafs, dead foliage, etc) but they decay over time and require maintenance. An alternative is to complement what is naturally available with loose-leaf netting which can be added to the area and used as a kind of shooting blind, where the individual places themselves behind the netting and facing the feeder. The netting can be fixed to trees etc, or supported with hide poles, but ideally the netting should be above head height when the individual is sat down. For air rifle distances, netting works best if the individual stays low and shoots through the netting. Evergreens and holly bushes work well to provide year round backdrops. If netting is to be used it is worth thinking about if it is going to be left in place or not. This is important in that if it is to be left in the woodlands, care and attention needs to be given to prevent other wildlife from getting tangled up in the netting (i.e., deer). This can be done by securing the base of the netting into the ground and laying substantial fallen tree branches around the base of the netting and stretching out a few feet, thus preventing deer from being able to stand too close. Otherwise it might be wise not to leave the netting in place at all. Pop-up hides are also a very useful solution. These can be secured in place and left in situ. There are no issues with wildlife getting

entangled here. Pop-up hides give the most cover which can also be very helpful in adverse weather conditions.

Figure 5: A pop-up hide in situ in the woodlands. These can provide year round cover and are of particular use in the winter months. The hide itself does not need to be particularly well hidden – it just needs to hide the individual.

Estimating distance accurately.

Distance between shooter position and the feeder is assessed directly via a laser rangefinder. Most units are typically accurate to within 0.5yds out to maximum distances of around 600 – 1200yds. A shooting distance of around 25yds is perfect and a range of 20yds-30yds would represent most typical situations for an air rifle. Using a laser rangefinder means the shooter knows the exact distance from their position to the target which facilitates downrange precision of shot placement on the quarry. It is also helpful to laser the area more generally and note landmarks (trees / rocks / terrain) that demarcate certain distances around the feeder and signify the limit that one will not shoot beyond. Such an approach facilitates the application of the findings from ballistic software (see below) and known verification from target practice into ones field practice.

Passive infra-red (PIR) wildlife cameras

To optimise the approach further, infrared wildlife cameras can be placed facing the feeder which will now capture all visits to the feeder. Grey squirrels are creatures of habit and it is now easier to establish their presence and feeding times while minimising the demands upon the time of the volunteer. Trail cams will reveal which squirrel species are present and when they like to feed. Once the data from the trail

cams have been consulted and grey squirrel activity noted, then the ambush can be planned thus also optimising the time of the volunteer even further. It is now simply a case of getting into the woods around 20mins before the timings on the camera images and wait.

Figure 6: A wildlife trail camera placed in situ and facing a feeder in order to capture all visits to it and provide data on the number of visits, numbers of grey squirrels, and feeding times.

Figure 7: Trail camera images reveal the scale of the problem. They also reveal times and locations of activity. The next visit to the woodlands is now fully informed.

Stability & comfort: Shooting sticks and seats

Targeting feeders requires the individual to sit and wait, sometimes for a couple of hours or more. It is important the individual is comfortable. Therefore, a shooting seat helps to ensure a degree of comfort and provides a sturdy shooting position. In addition, shooting sticks can be used to ensure stability for the rifle. Tripod shooting sticks are very stable and some models are height-adjustable affording the volunteer considerable variability in the range of angles that can be supported with considerable ease.

Figure 8: Optimised modern ambush techniques utilise a steady shooting stick and seat. It is important the shooter is comfortable and stable. In the summer months hides can also be unnecessary and simply using the natural woodland and remaining still can be very effective. Face and hand coverings are essential for work at air rifle distances.

Thermal Imaging / Thermal spotters.

Thermal imaging can be used for both feeder-based and stalking approaches. The imager is something of a game changer showing heat signatures and thus revealing quarry that would otherwise be missed by the naked eye. Thermal is not only useful for locating quarry for lethal removal, but also to assess the area in general as it is often the case grey squirrels can be spotted in the distance and a healthy appreciation of numbers in the area can be made (and guide future visits). Furthermore, thermal can inform the individual with regards more general wildlife in the area.

Figure 9: Thermal imaging is a game changing technology revealing the heat signatures of grey squirrels in the woodlands that might otherwise be missed by the naked eye. The thermal signature of the grey squirrel can be easily detected out to +80yds and beyond.

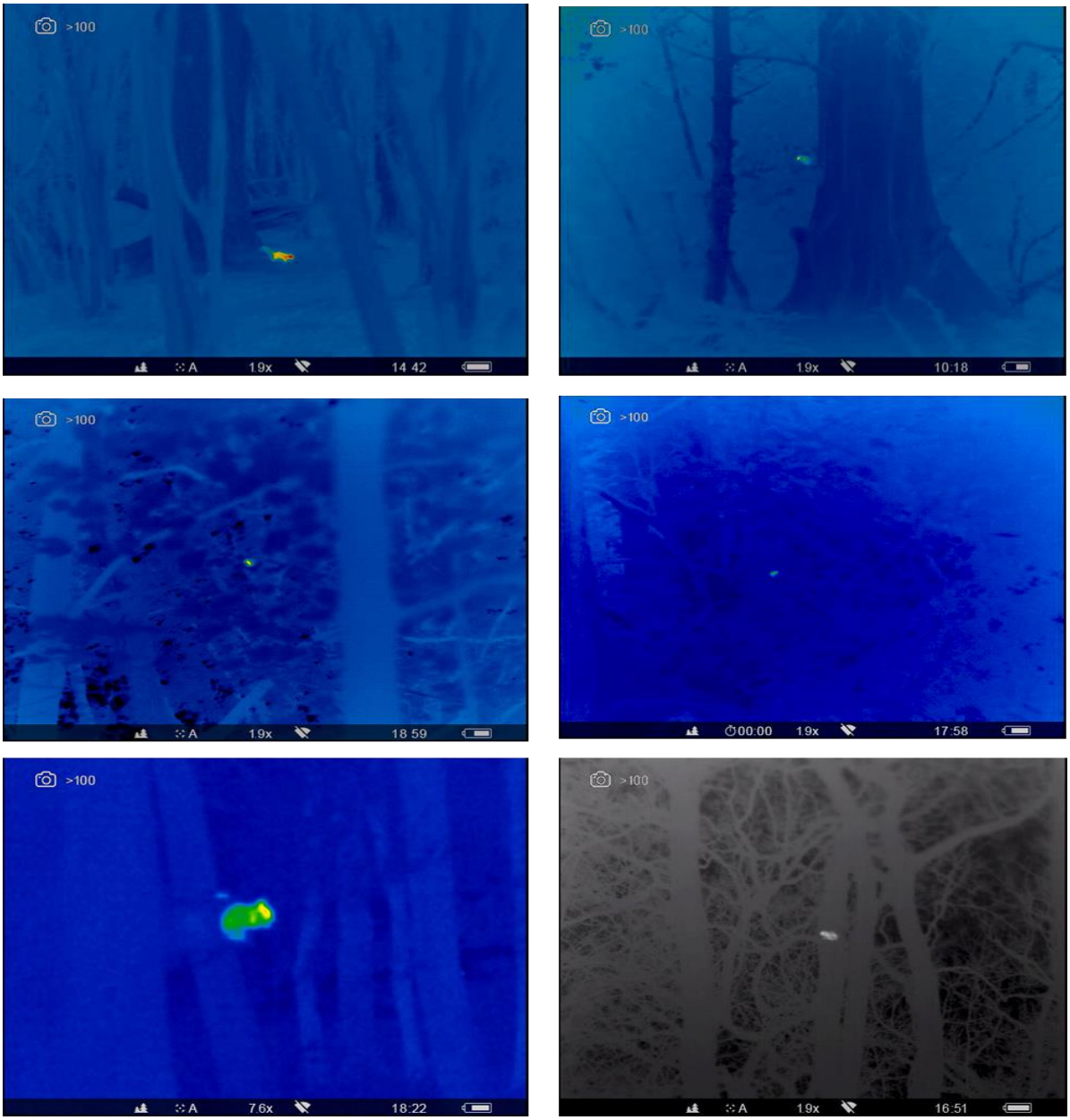

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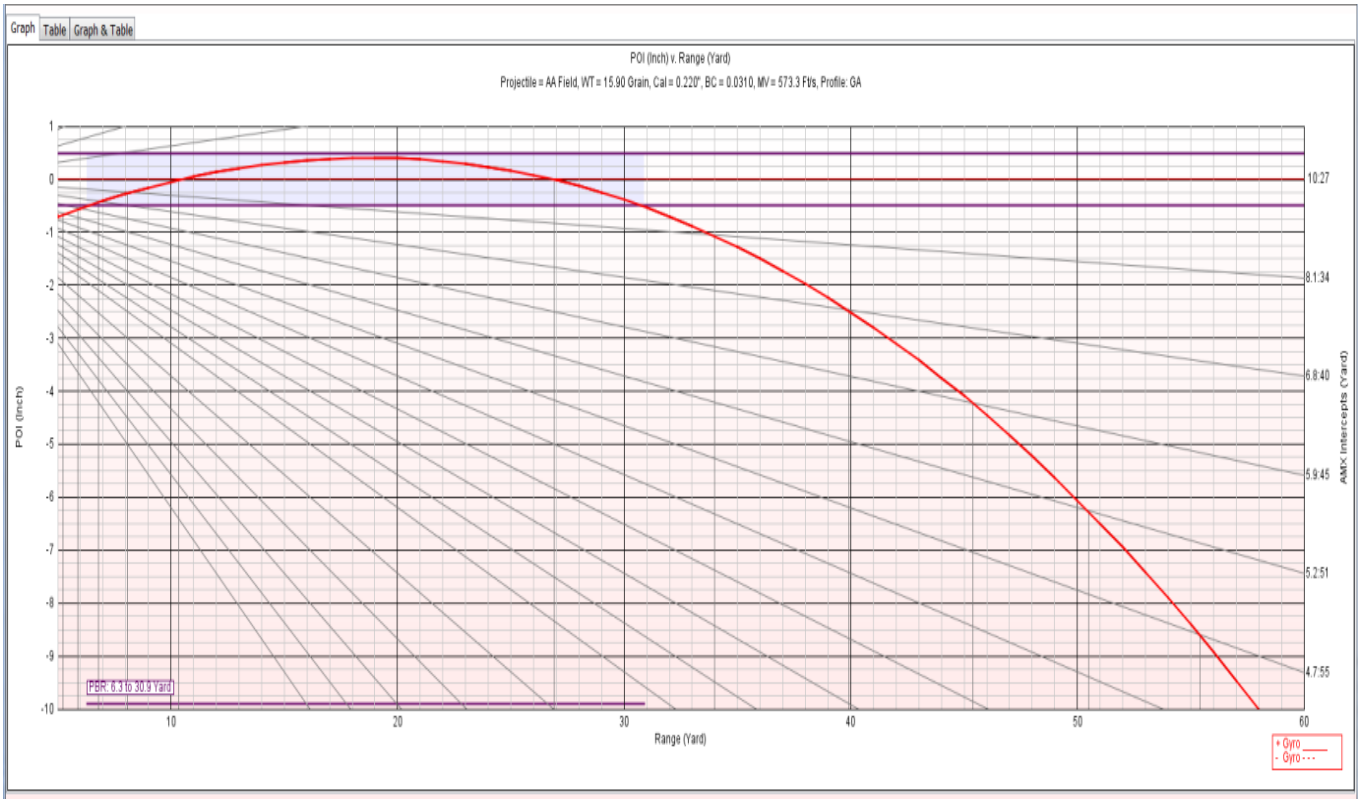
Figure10: With the use of ballistic modelling software (coupled to confirmatory practice on targets) the shooter can plot the trajectory of the pellet thus reducing guesswork over distance.



Part II: Overview: The manor house project

The project is located near to the Cumbria / Lancashire / Yorkshire border region. There are currently 10 sets of woodland subscribed to this project from four separate landowners. Several woods belong to a large Manor house estate. Other woods belong to two farming families (one each side of the manor house estate), and finally a landowner who lives away but rents his land to local farmers also contributed two additional woodlands. Local farmers have reported that these woodlands discussed here were indeed home to red squirrels when they themselves were children and were growing up in the area (circa 50 years ago). In addition, small populations of red squirrels are currently in residence less than 1 mile to the West, 1 mile to the East of this project (on other country estates) and 10 miles north of this region.

Estimates of the scale and size of the woodlands were made using Google earth maps and the distance / area function. Plotting from the furthest point south, through to west, north and then east including all lands within this perimeter, results in an approximate 243 acres in size. Of this the 10 separate woodlands make up around 70 acres in total (almost 30% of the total area). In between the woodlands are open fields and pastures used predominately for sheep and some cattle farming. Natural hedgerows and dry-stone walling provide potential highways for the grey squirrels to utilise while moving from wood to wood. The largest distance from the tip of one piece of woodland, to the one furthest away from it (and in a straight line) is 1.11 miles, with distances between neighbouring woodlands ranging from 339ft to 2,131ft and an average distance of 1,020ft. These distances are well within the foraging and localised migration range of the grey squirrel. There are no public parks in this region and only one public pathway which goes through an open field.

Importantly, there are no woodlands within the perimeter that are not part of the project. This helps to ensure the success of the project by either removing all grey squirrels, over time, or significantly suppressing their numbers to a level that would not be possible with more modest coverage. Therefore, a large footprint of pressure can be applied. Of course there will always be woodlands outside of projects that are not being controlled, and subsequently are in a position to provide incoming grey squirrels to the controlled area. However, having access to a large number of woodlands and all woodlands within a respectable area can help to ensure a wider clearance of the area and the subsequent control of the area.

Table 2. An overview of the woodlands for the current case study. The names of the woodlands are pseudonyms.

Location	Acres / size	Notes
The “Big Wood”	22.88 acres	Predominantly hardwoods
House Farm wood	8.37 acres	Predominantly hardwoods
Tarn Wood	10.62 acres	Predominantly hardwoods
Cow Wood	10.88 acres	Predominantly hardwoods
New Wood	3.90 acres	Predominantly hardwoods
Rectangle wood	3.94 acres	Predominantly hardwoods
Tiny square wood	1.24 acres	Predominantly hardwoods
Tiny red wood	0.96 acres	Predominantly hardwoods
Round wood on the hill	1.21 acres	Predominantly hardwoods
Soft wood	1.98 acres	Predominantly conifers / softwoods

[1]Note: The term “Predominately hardwoods” means that while conifers may well be present – it is in extremely low number to hardly any at all. In most cases hardwoods (of various species) dominate the woodlands.

[2]Note: It is interesting that even though the majority of these woodlands consist predominately of hardwoods, there once was a population of red squirrels residing in this region suggesting that the local ecology was sufficient to support them.

Additional Notes

The Big wood = a reasonably wide beck flows through the wood and can be quite strong if carrying enough water from rainfall. The beck cuts through the middle of the wood and the wood follows the beck as it passes through the manor house estate. For directing grey squirrel control, the wood was spilt up into three sections, one either side of the beck and the final section near the main manor house (which is referred to as House wood). Its nearest neighbour is Tarn wood on one side and House Farm wood on the other.

House farm wood – an L-shaped wood on the top of a small rise and one of the more isolated relative to neighbouring woodlands. Due to its mildly elevated and exposed position it does experience a lot of wind / harsh weather. Its nearest neighbour is the Big wood.

Tarn wood – Originally this consisted of mixed conifers and hardwoods with a tarn at one end – but substantial felling took place circa 2019 in the middle of the wood and a hardwood replanting programme replaced the majority of the conifers. It now has a hardwood section and both ends of the wood with a cleared / bare and replanted section in the middle. Its nearest neighbours are the Big wood and Tiny square wood.

Cow Wood – A large and predominantly hardwood region. Of the conifers that are present, the majority have fallen or are in the process of leaning / toppling. There are lots of hazel trees in one section. A tiny beck / stream flows through the middle of this wood. Its nearest neighbours are New wood, Round wood on the hill and Rectangle wood.

New wood – A slightly L-shaped wood with lots of old / aged hardwoods and fallen trees. A small stream / drainage ditch runs at one side of the wood.

Rectangle wood – A small section of hardwood trees near a track with a beck running through this section (same beck as runs through Cow wood – but this is downstream from there), there is a cleared space with replanting on going and then the main wood.

Tiny square wood – a really small wooded space of mixed tree species and a small concentrated conifer section opening out towards a more spacious hardwood section. Nearest neighbour is Cow wood.

Tiny red wood – not many trees in here – estimate of fewer than 120 – predominately hardwoods. It is situated on the opposite side of a main road to its nearest neighbouring wood – The Big wood. Tiny red wood is the closest wood (in a straight line) to a known small colony of red squirrels approximately 1-mile away and across a large river on another estate.

Round wood on the hill – not a very dense wood – but mixed conifers and hardwoods are present. The wood stands alone on top of a small hill / rise and sits in the middle of (and is surrounded by); (i) Rectangle wood, (ii) Cow wood, and (iii) New wood.

Soft wood – a humble sized wood distinctive in that it predominately consists of conifers. Its nearest neighbour is Cow wood. There is no evidence of any squirrel species in this wood at present (no camera images), though it is regularly monitored via wildlife trail cameras for signs of any incoming individuals.

Results

Descriptive overall statistics for the project are given in Table 3. It is important to note that these numbers reflect moving around several woodlands and thus, whenever shooting a new section, numbers will be high until, after repeated sessions, the effects of constant pressure emerge. In addition these overall numbers pertain to the project that also included the addition of new woodlands in 2020 which in turn accounts for the increase in culls that year. Therefore, these data do not necessarily reflect pressure being applied to exactly the same spaces in all years. Irrespective of these observations, a clear negative trend emerges.

Table 3. The number of grey squirrels removed via shooting with an air rifle over the period.

Year	No of Culls (all woodlands)
2018 (from May) – 2019	69
2019 – 2020	98
2020 – 2021	128
2021 – 2022	94
2022 (Jan) – 2022 (September)	54
Total =	**443**

The increase seen in some of the latter years (Table 3) might seem to go against the notion that shooting is effective at removing grey squirrels in the area. However, there are several important observations that modify this interpretation. First, it is important to note that shooting did not start until late May in 2018 (there were only 7-months of shooting for that year), whereas in 2019 culls represent a full 12-months of pressure. Second, in 2020 three new additional bits of woodland were added to the project. To examine this further and provide a more representative account of potential reduction in numbers, Figure 11 represents the successful removal of grey squirrels now separated in terms of the original project (as it started in 2018) and the additional woodlands added from March 2020.

As Figure 11 shows, once separated in this way both components of the project demonstrate a clear reduction in grey squirrels being removed from the woodlands year-on-year. With the frequency of visits to the woodlands being constant, this supports the notion that fewer culls represent fewer numbers in the woodlands in the first place. Pressure from shooting with air rifles, targeting feeders coupled to winter stalking is associated with a clear reduction in numbers. Between 2020-2021, the blue line (original project) deviates while, at the same time, there is a strong fall in culls on the three new woodlands data (red line). Arguably the most accurate way to interpret this is that the focus placed on the three new woodlands (and the attempt to make an early impact) detracted from the ability to maintain exactly the same pressure as previous years on the woodlands of the original project. Therefore, the co-occurrence of a steep drop in one component, and a slight levelling off of another, reflects a bias in effort at that time – at the cost of attention placed elsewhere. Note also that in the 2021-2022 cycle both components show a clear reduction in culls.

Figure 11: The number of grey squirrels removed from woodlands separated in terms of the original project and the additional three woodlands added in 2020 (dotted lines = trend lines for both components).

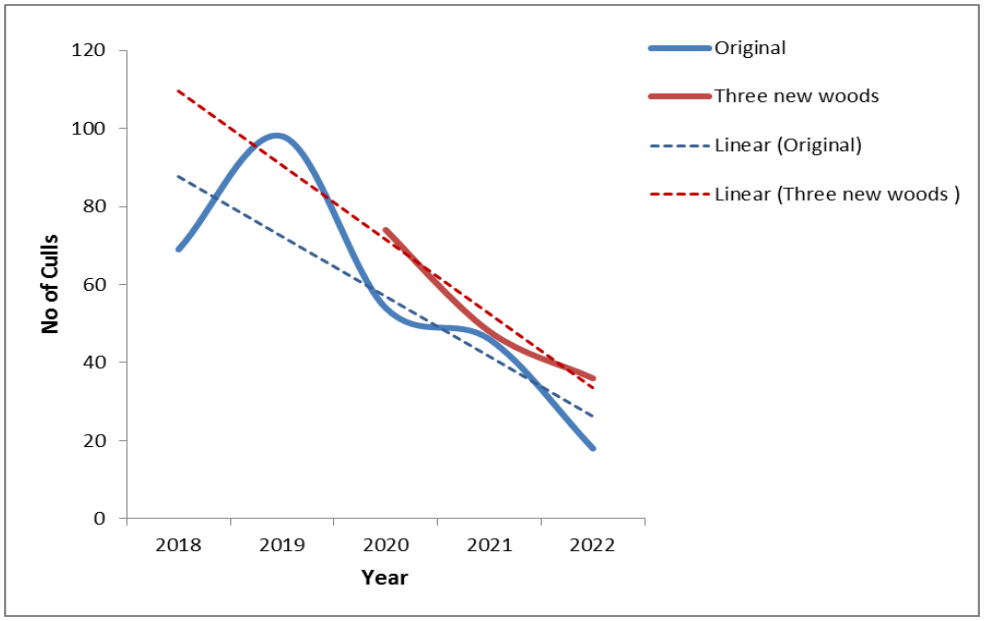
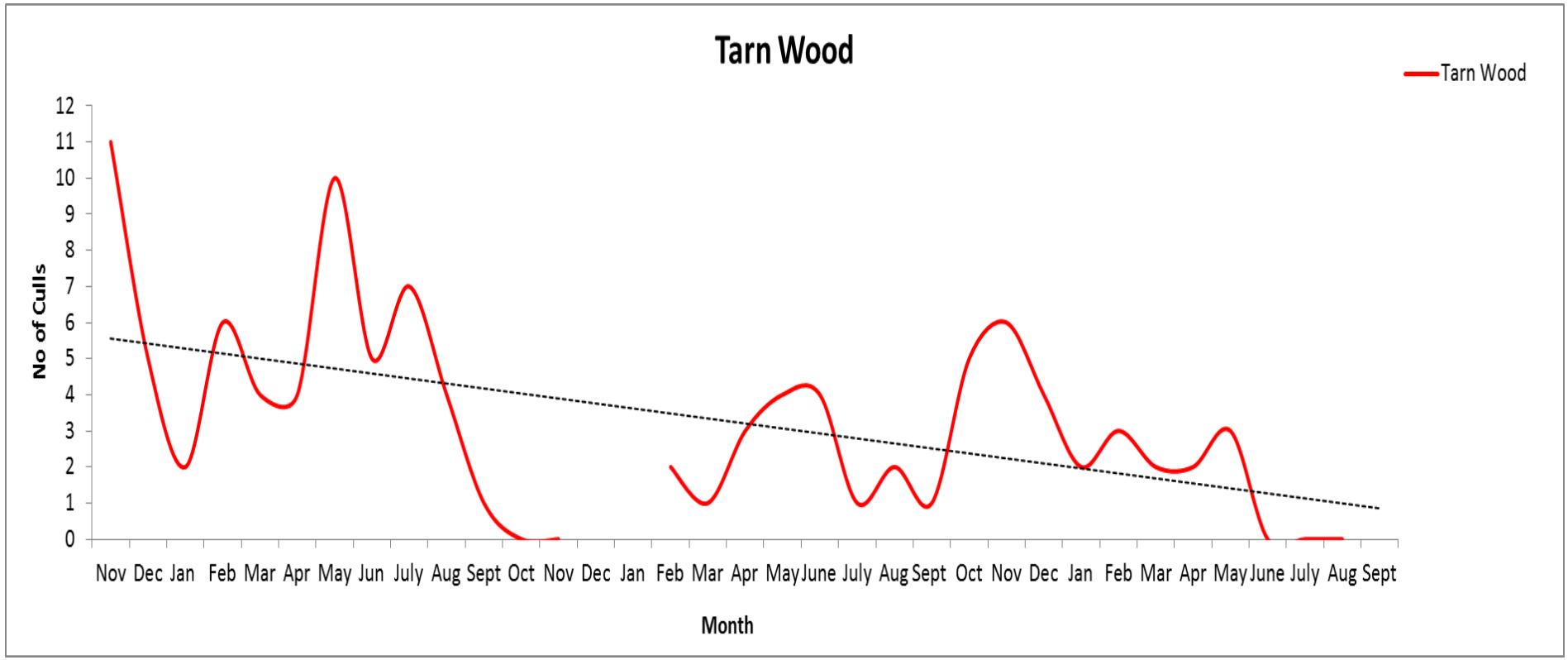


Figure12: Example data from two periods of shooting in Tarn wood. Missing data represents a period when this wood was not being shot (following two months of no sightings / culls). Initial shooting tends to bring good numbers and this is true for the start of most projects. There also tends to be good shooting to be had on the feeder in the months May through to July, including kits from the first breeding season. Quiet times on the feeder tend to occur from mid-August until the end of September when the grey squirrel spends a lot of time in the tree canopy eating the natural fruit and nuts. Note – the peaks on the graph generally correspond with when young grey squirrels are 'kicked out' from their home ranges (i.e., incoming dispersals).



Individual observations

1# Grey squirrels have been noted out in the middle of open fields, at least 60yds from the cover of woodland and / or hedgerows. They appear to be foraging, perhaps for buried nuts from the previous cycle. While such behaviour may be commonplace with urban grey squirrels or those seen on a University campus / city park, this is rare in the more remote and 'wild' sections of the countryside where predators may also be more proximal.

2# On occasion grey squirrels have been observed travelling quite a distance to come into the feeder. Winter shooting and thermal imaging has helped to quantify this behaviour. On one occasion a grey squirrel was observed leaving the "Big Wood" travelling straight across an open pasture field, jump up on top of a dry stone wall and run along the top of it, enter Tarn wood, scale the tree tops, navigate towards the tree hosting the feeder, drop to the floor and then jump to the feeder. The estimated distance of the visible part of this journey was approximately 180yds.

3# During the project, Tarn wood (which has had a number of conifers thinned out due to a replanting scheme and is now predominantly hardwoods) has been cleared of grey squirrels twice. This has been established by; (i) feed no longer being taken, (ii) no camera images from the in-situ wildlife camera, and (iii) sustained periods of no sightings / shooting while in the wood. In all instances this period of no activity has lasted for about 3.5 months before the cameras start picking up the first signs of new incoming grey squirrels. Once this has been detected the feeder is then reactivated and shooting begins again.

4# There is some anecdotal evidence of a social hierarchy in the groups of squirrels noted on the feeders. Here, dominant grey squirrels would chase others away and on many occasions the other squirrels would wait patiently in the trees proximal to it. Interestingly, once the dominant squirrel was removed – sightings on the feeder can actually increase as the behaviour of the other grey squirrels appears to represent more of a free-for-all on the feeder.

5# In terms of natural predators, stoats have been observed in the area by the volunteer during the afternoons and a mink has been recorded on the wildlife cameras (in one area) – but the latter only during the night hours. Several raptor species are present in the region – though it is unclear if they are predating on kits (no instance has been documented). Species include; Sparrowhawk (rarely), Buzzards, Kites, and Tawny owls.

Improvements

While the removal of approximately 450 grey squirrels does index a level of efficiency this needs to be balanced against remaining numbers from breeding and incoming migrating grey squirrels. In addition, it can be argued that this number could be seen as being more effective / efficient had it occurred sooner. These are is indeed fair observations. However, it is important to carefully assess what we mean by *effectiveness* and indeed *efficiency* while also remaining practical and pragmatic with regards situational constraints.

(i) Effectiveness & Efficiency

What is meant by the term *'effectiveness'*? How do we know if our methods truly are effective and efficient? When it comes to the concept of *'effectiveness'*, then surely a method can be deemed to be *effective* not just by the occurrence of large numbers of culls being made, but if that method removes more grey squirrels than can be replaced via breeding or incoming migration, year on year. Such a trend would predict not just the removal of grey squirrels or the steady control of numbers, but the actual suppression and potential clearance of them from the local microenvironment. The data presented here from this case study are commensurate with this conception of *effectiveness*. Not only have a large number of grey squirrels been removed, but the numbers currently being removed from these woodlands are substantially lower relative to previous years and the downward trend in numbers continues – though numbers remain at a non-zero level. This is the case for all the woodlands being actively covered on this project. This suggests that the grey squirrel is not breeding at a rate faster than they are being removed. This observation may also speak to the incoming migration of grey squirrels from outside of the perimeter of this project. Migration is a worry as many of the woodlands that now have significantly reduced numbers of resident grey squirrels (based on the evidence from shooting and wildlife trail camera visits to feeders), are now near-empty yet the woods remain attractive and accessible to incoming greys – and competition from the social hierarchy of resident grey squirrel will be low as there simply is not the critical mass present that there once was.

However, if migration were a serious problem undermining the efficacy of the method this would make the clear prediction that a steady state of squirrel culls would occur over the 4-year period. That is to say, there would be no net reduction in the number of culls or at the very least – the effectiveness of the method would level off at a given amount and then remain constant. Clearly this is not the case. While incoming squirrel migration will be taking place, constant pressure on the woodlands appears to be preventing them from gaining a stronghold in the area. Therefore, neither breeding nor migrations are offsetting the effects of concentrated and year-long sustained shooting. Put simply, there are far fewer grey squirrels in these woodlands than there were and there is a year on year drop in the numbers seen and removed which cannot be explained by fewer visits to the woodland (the frequency of visits to the project was relatively constant over the 4-year period and continues at that rate).

The effectiveness of the current case study is limited in that only one shooter is contributing to the project. If more dedicated enthusiasts came on board this would indeed allow for a broader footprint of pressure to be implemented. However, this is not a limitation of the shooting method per-se, just how (through reasons of pragmatism in this case-study setting) the method was implemented here. This observation also speaks to the issue of '*efficiency'*. In terms of the time taken to reach a satisfactory demonstrable reduction in numbers, then efficiency in this sense is indeed related to the time taken to reach that state. Therefore it would be more efficient to have reached 450 grey squirrels after 3, 2, or 1 year which would be possible if (i) the shooter had more time to invest (he is a volunteer shooter in his spare time), (ii) there were more guns on a given project, or (iii) if shooting

were complemented by other methods being pursued with equal vigour (i.e., trapping). In contrast to these worthy observations, the fact that the number of culls reduced year on year, is consistent with the actual number of grey squirrels in the area reducing and is actually all the more impressive for having been achieved by one shooter, acting in his spare time. Therefore the current case study evidences the efficacy of what can be done at a base level. One can imagine how issues of efficacy could be improved if projects like this one were expanded. However, this is simply an issue of scale and not a limitation in the shooting method per-se. Therefore, these observations do not undermine the effectiveness or the efficacy of shooting.

If cost-effectiveness is used as a metric of efficiency then from the landowner's perspective the project is 100% cost effective as this project has not incurred any cost to any of the land owners. This is not a situation we can expect to be rolled out or applied universally across other projects and so solutions in this regard should be considered. If time cost is being used then calculations not just on the time period invested for the numbers removed, but also the time invested that resulted in no culls needs to be examined. Sitting in a hide for 3-hours and having nothing to show for it could indeed be seen as being inefficient in terms of time investment. However, such instances are more likely to occur when numbers are low and thus, are an unavoidable consequence of success. The feeder method works well for most of the year and though there can be periods when activity on the feeder is low (late summer), this does not last for long. In addition, feeder methods can be complemented with woodland stalking during the winter months (November – February), can be vastly improved with thermal imaging, and further complemented (when possible) with drey poking and trapping.

To summarise, in the hands of a competent experienced shooter, air rifles coupled to optimised feeder / stalking methods are effective not just at controlling, but significantly suppressing the numbers of grey squirrels in rural woodlands. If carried out by volunteers or squirrel groups then they are financially efficient / cost effective for the landowner. The effectiveness of the method is dependent on; (i) constant pressure being applied over as large a collection of woodlands as is possible, (ii) constant pressure being applied throughout the year, and as suggested above, (iii) the burden of projects being shared by multiple shooters. Overall, the addition of trapping and using shotguns along with drey poking can represent a more holistic approach on large estates – where a broad portfolio of methods can make a huge contribution. Consequently, it is erroneous to look to one method, one singular approach, to suit all situations and contexts. Going forward the key will be to know which method should be pursued and in what context. This can be seen as a 'mapping' exercise of optimising ones approach, by drawing on the most appropriate methods (or a combination of them) for a given scenario. Irrespective of the method chosen, it will need to be applied in a sustained and coordinated manner in order to ensure success with regards turning the tide and achieving year on year reductions in the number of grey squirrels in our woodlands.

Comparative issues

Effectiveness and efficiency should also be mediated by comparing shooting methods to alternatives such as; (i) trapping (live traps and lethal ones); (ii) contraception, and (iii) species introduction. Trapping can be very effective, but also very time consuming as traps must be checked regularly. Therefore, they may be preferred more by gamekeepers and onsite professionals, but can be less pragmatic for enthusiasts working in a voluntary capacity in their spare time. It is not tenable for volunteers to check live traps multiple times a day, or empty and re-set lethal traps with similar regularity through the day. In addition, many are reluctant to live trap in regions containing red squirrels due to the possibility of stress being induced into the animal. Although non-lethal traps will

not physically harm a red squirrel and they can be released easily, the stress and anxiety induced is to be avoided. The notion of contraception is interesting but still in development and thus as a method its degree of potential efficacy awaits clarification. At the very least, contraception would not be an approach with instantaneous effects on removing grey squirrels. The grey squirrel will still live for a few years with the opportunity for breeding removed – but over that time woodlands are still being damaged and red squirrels are still potentially being infected with the squirrel pox virus. The notion of introducing species like the Pine marten is hotly debated. While there may well be a theoretical merit, drawbacks and limitations need to be assessed and much of these may well be context dependent. Pilot projects of reintroduction are currently underway. Nonetheless, claims against the efficacy of shooting need to be balanced with a consideration of what the baseline is. Ineffective? How, and by what measure? There are of course limitations with all shooting methods (and all of the alternatives listed above) – but limitations can be mediated and a limitation in one method does not render it ineffective. The main limitation with shooting, as a method, appears to be related to how vigorously it is applied and pursued. Even if drey poking is a tenable approach in a given area, it cannot be used all year round and so is not a system of constant pressure. Air rifles on the other hand, applied in the manner outlined here, can be applied throughout the year leading to sustained pressure being placed on the localised grey squirrel population.

Costings

While large country estates may well have access to air rifle methods through hired staff (i.e., gamekeepers / forestry workers) it is unlikely to be cost-effective for the estate to have staff covering feeders throughout the week, month, and year. This is where the volunteer / enthusiast can help. The vast majority of the air rifle community involved in shooting live quarry (be that as part of pest control or conservation) do so in a voluntary capacity. They may operate on their own or, in the case of grey squirrel control, they may be part of one of the many 'squirrel groups' coordinating their efforts across large areas (particularly in the north of England). The cost of the shooting is typically shouldered by the shooter. Leaving aside the costs of a multi-shot PCP rifle (upwards of £700 would be typical), telescopic sights (£250 - £500), and pellets (£18 per-tin), plus general paraphernalia for pest control / hunting (shooting seats, shooting sticks = £150), and outdoor apparel, there are additional squirrel culling specific costs. These would include feeders (not to mention the feed itself – predominately peanuts), PIR activated wildlife trail cameras (plus batteries and camera cards – units can be purchased ranging from £50 - £350 each), hide-netting and poles (£50 -£110) or pop-up hides (£60 - £120). Many dedicated enthusiasts also now invest in thermal imaging spotter units (£1,200 - £3,500). Squirrel groups can support shooters with free feeders and, on occasion, free feed (maize), but the financial burden and running costs are primarily carried by the enthusiast and not necessarily the land owner / estate. This is perhaps something that could be explored going forward where estate owners may be able to provide some support with the overall financial burden with the project still remaining financially viable.

Volunteer Red squirrel groups

In the magazine for the British Association for Shooting and Conservation (BASC), Braithwaite reported findings from the West-Lakes Squirrel Initiative (WLSI) showing increased sightings of red squirrels coinciding with noted culls of grey squirrels. A subsequent offline analysis of these data revealed a correlation coefficient of around .70 {see Shooting and Conservation, *'Fighting Back'* Nov

2017 to view the original article} between these two sources of data. In the north of England there is a large and growing movement of people getting involved in red squirrel and woodland conservation. These volunteers may go out and report sightings (of either species) helping the shooters coordinate their efforts, they may report sightings of red squirrels with suspected parapox virus, or report sightings of damage to woodland trees. In addition to these admirable efforts, the shooter (typically with an air rifle) will seek to intervene as when necessary in an effort to address the situation. The presence and contribution of these groups has been largely ignored in debates surrounding the efficacy of air rifle methods. As a consequence, no detailed analysis of the efficacy of volunteer red-squirrel conservation groups has ever been carried out. While localised successes are reported (Braithwaite 2017), the true impact of these groups, as an en-masse effort, awaits evaluation. Future assessments of the efficacy of shooting in the control of grey squirrels will need to fractionate the different forms of shooting (shotguns, cartridge rifles, air rifles), with particular attention to the use of air rifles (as they have been ignored in reports to date). In addition, a clear examination of the 21st Century culling methods outlined in this case study and the involvement of many volunteer red squirrel conservation groups is now unavoidable. Once done, the utility of air rifles and volunteer groups will be difficult to avoid by organisations like the Forestry Commission, Woodland Trust, and others if they are serious about the suppression and indeed removal of grey squirrels from regional areas.

Going Forward

The findings presented in this case study establish that shooting grey squirrels with air rifles and utilising an optimised approach is an extremely effective method for suppressing numbers of the grey squirrel. It is effective and humane. Having done this it should also be acknowledged that a more holistic approach will likely pay even more dividends with perhaps trapping and drey poking being highly complementary[2]. There are ways to optimise these methods as well to ensure they provide an effective and efficient solution. Government grants are becoming available for woodland replanting schemes which can be red-squirrel friendly. Going forward it would be beneficial if a component of these grants went to the volunteers and / or squirrel conservation groups to provide some financial assistance with implementing some projects – especially larger estate projects. The financial amounts involved need not be large. A modest investment would help support efforts across many hectares with feeders, feed, wildlife trail cameras, hides, etc. Volunteers would still be giving their time freely and so such costs for resources should be balanced against the potential (and avoided) costs of salaried members of the estate team spending the hours in the woods when they are likely needed elsewhere.

[2] Drey Poking is not viable in woodlands containing grey and red squirrels as it is not obvious what species is occupying a given drey. Therefore there are constraints on where drey poking can be utilised as it is likely untenable in some contexts.

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